A PRIORITIZATION METHODOLOGY
for
CHRONIC ENVIRONMENTAL DEFICIENCIES

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EXECUTIVE SUMMARY

Chronic environmental deficiencies (CED) are locations along the state highway system where recent (last 10 years) and frequent (three or more) maintenance and/or repairs to the state transportation infrastructure are causing impact to fish and fish habitat. The purpose of this report is to provide a scientifically based prioritization scheme that will prescribe the order of CED correction. This will front-load the benefits of a program designed to correct the worst problems first, as measured by expected increases in salmonid fish production and expected reductions in transportation concerns such as safety and repair costs caused by the CEDs. The process for prioritizing CEDs is collaborative and includes technical (engineering and biological), construction/maintenance, and policy components. It is an integral part of a cycle that includes CED site identification, prioritization, scoping, design, funding, permitting, construction, and evaluation. Data for the prioritization are supplied in several steps of the cycle, which are summarized in a Priority Index (PI) for each CED. It is calculated as follows:

$$_{CED}\,\mathrm{PI} = \sum_{AllSpecies} \sqrt[4]{[(FPH)xEDC]}$$

The product of the three PI factors F, P, and H estimates the adult equivalent salmonids that would benefit from correction. E represents the expected effectiveness of the correction, D shows the fish stock status identified by SaSI, and C is the net cost of the correction, considering future savings in repair and maintenance costs. Value added factors that address ESA stock status, matching funds, and the breadth (scope) of correction are applied to the base PI to more fully reflect a project's priority. In addition, a formula is prescribed to compare correction strategies for multiple sites.

The prioritization methodology was tested on 12 individual sites and five site combinations on the North Fork Nooksack River, Snoqualmie River, Sauk River, Hoh River, White River, Naches River, and Red Cabin Creek (Skagit River). The single site PIs ranged from a high of 66.55 for the Warnick Bridge site on the North Fork Nooksack to a low of 3.47 for the site in the non-anadromous zone of the same river and yield an appropriate spread for selecting projects for retrofit. With value added parameters excluded, the range was 55.46 to 3.47, which is similar to that experienced in the fish passage prioritization. The number of adult equivalent salmonids affected on an annual basis averaged 3,395 and ranged from 24,915 to 72.

Using the PI to prescribe order of correction obviously maximizes fish production benefits. In an example using the four lowest and four highest priority projects in a four-year correction schedule, the benefits are much larger when correcting the CEDs with largest PIs first (109,342 fish versus 38,402 fish in a four-year time span). The stream of benefits would extend indefinitely into the future with durable retrofits. It is also important to note that significant proportions of these fish are depressed and/or listed under ESA, which further elevates their importance. Transportation benefits include elimination or minimization of future repair and maintenance costs as well as associated safety issues. In addition, there are intrinsic benefits to an environmental retrofit because of the increased value of the road infrastructure. In most cases, the timely retrofit of a CED site also will circumvent future catastrophic road damage, the repair of which would normally exceed the correction of the CED. These transportation considerations coupled with fish benefits should easily substantiate the overall cost efficiency of the CED correction program. Acceptance of overall program cost efficiency would then reduce the retrofit arguments to the rate of CED correction using the prioritization scheme described in this report.

SCOPE AND BACKGROUND

Chronic environmental deficiencies (CED) are locations along the state highway system where recent (last 10 years) and frequent (three or more) maintenance and/or repairs to the state transportation infrastructure are causing impact to fish and fish habitat. There are 100 ± 40 such sites estimated for state-owned roadways in Washington (Bob Bicknell, personal communication[1]). The State Department of Fish and Wildlife (WDFW) and the State Department of Transportation (DOT) desire long term solution to these problems, not only to benefit the fish resources of the state but also to facilitate the efficiency and cost effectiveness of the transportation system. The purpose of this report is to provide a scientifically based prioritization scheme that will prescribe the order of CED correction. This will front-load the benefits of a program designed to correct the worst problems first, as measured by expected increases in salmonid fish production and expected reductions in transportation concerns such as safety and repair costs caused by the CEDs.

A prior cooperative endeavor by these two agencies was initiated in 1991 to address a similar problem related to fish passage at state-owned roadways. The prioritization methodology developed in that cooperative process resulted in a concise, scientifically based fish passage priority index (PI) that expresses each fish passage project's relative priority that includes production benefits of affected fish species with consideration of project cost. This CED treatise uses the PI approach, but tailored to address CEDs. Each parameter in the PI is examined and where appropriate modified to address the differences between a fish passage correction and a CED correction. The result is a CED methodology that will facilitate a joint process between staff of the two aforementioned agencies in development of a prioritized list of CED correction projects on DOT-owned highways across the state.

A secondary objective of the CED prioritization methodology is to provide an index that results in a range of values comparable to that generated by the fish passage index. This objective is problematic because fish passage addresses <u>access</u> to habitat rather than the <u>integrity</u> of habitat itself in a CED. To make these issues comparable, the base parameter of both indices uses the <u>potential</u> adult equivalent fish that are either lost annually by a barrier that makes habitat inaccessible or that are lost annually because of adverse effects to fish habitat resulting from a CED. The adult equivalent metric represents fish that would, on an annual basis, survive to spawn or be harvested as adult fish, while accounting for natural mortality. Subadult fish are discounted to a number that would have survived to adulthood in the absence of the subadult harvest. This approach in addition to keeping the number of modifiers in the indices the same results in similar ranges for both indices.

[1] Biologist and DOT liaison, Washington Dept. of Fish and Wildlife

THE CED PRIORITY INDEX ($_{CED}$PI)

The variability in maintenance/repair frequency and costs, costs of more permanent corrections, amounts of fish habitat affected, and species utilizing affected habitat throughout Washington State make the characterization and prioritization of corrections to chronic environmental deficiencies on DOT-owned roadways complex. The process proposed herein uses a Priority Index model to consolidate these and other related factors that affect a project's feasibility into a manageable framework for developing a prioritized list of correction projects. The result is a numeric indicator giving each project's relative priority that uses production estimates for anadromous and resident salmonids as the base parameter. Site-specific modifiers are used to adjust this base parameter. The Priority Index (PI) for each CED is calculated as follows:

$$_{CED}\text{PI} = \sum_{AllSpecies} \sqrt[4]{[(FPH)xEDC]}$$

Where:

$_{CED}$PI = CED Priority Index

< The PI summarizes the relative project benefit considering cost.

< The PI is actually the sum ($3_{\text{all species}}$) of individual PI values, one of which is calculated for each species present in the area affected by the CED (*e.g.*, PI_{coho} is added to PI $_{\text{chum}}$ to obtain $PI_{\text{all species}}$).

< The quadratic root in the equation is used because it provides a more manageable number and represents a geometric mean of the four factors used. The first factor, which is the product of areal habitat quantity (**H**), fish production potential per areal unit of habitat (**P**), and an frequency of repair impact factor (**F**), is expressed as adult equivalents of fish on an annual basis affected by a CED site. The other three factors (**E**, **D**, and **C**) are dimensionless modifiers to the number of adult equivalents.

F = Frequency of historical maintenance and repairs

< CEDs are defined as sites that undergo at least three maintenance or repair activities in a recent 10-year period. These activities can occur within any year or across multiple years. **F** expresses the frequency of these activities that adversely affect fish habitat in the immediate and contiguous area. Larger numbers mean higher frequency, which translate to more negative impact to fish.

< A value of 1/3 equates to a frequency of 3 activities in the 10-year period. A value of 2/3 equates to 4 or 5, while a value of 1 expresses 6 or more activities. If a site meets the definition of a CED, but the exact frequency of activities is unknown, then a default value of 2/3 should be used. It should be noted that a maintenance/repair activity or even the character of the CED site absent repair activity can have a multiple year effect on fish. Therefore, the modifier correctly expresses a frequency higher than the quotient of number of activities in the 10-year period.

P = Annual adult equivalent production potential per m^2

< **P** estimates the number of adult salmonids negatively affected by the CED on an annual basis. In the CED PI, this number can be interpreted as either the adult equivalents lost in the past or the adult equivalents expected to be produced in the future with a permanent, fish-friendly correction.

< The values (adults/m^2) are species specific; chinook salmon = 0.016, chum salmon = 1.25, coho salmon = 0.05, pink salmon = 1.25, sockeye salmon = 3.00, steelhead = 0.0021, bull trout/Dolly Varden = 0.0007, searun cutthroat trout = 0.037, and resident cutthroat/rainbow trout = 0.04. The last is assumed to always be present at a CED site, so should be considered a surrogate for other salmonids such as whitefish that may be present. The WDFW web site (http://wdfw.wa.gov/) and its link to SalmonScape along with salmonid stock inventory reports (SaSI)(1998, 2000, 2002) document the presence of the other species. These production values were derived in a comprehensive review among biologists in WDFW and are documented in the Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual (APManual) (WDFW, 2000). It should be noted that adjustments to these values resulting from varying degrees of sympatry or the presence of nonnative brook trout and brown trout are not included in the CED PI because the number of CED sites would not warrant this increased degree of precision for priority separation.

H = Habitat affected in m^2

- **H** is measured/calculated from physical surveys and CED site maps and drawings and gives greater weight to larger sites that affect larger amounts of habitat. The most precise estimates of habitat would be derived from the methodology prescribed in the APManual. However, two reasons reduce the need for the vigor of this methodology. First, there are far fewer CED sites compared to fish passage and water diversion problems addressed by the manual. Second, CED sites are included in rigorous reach analyses that should result in detailed engineering site drawings which can be assessed for spawning and rearing areas by qualified fish biologists.

- Perhaps the most difficult task is determining the exact <u>linear</u> boundaries of a CED site because a reach analysis typically encompasses an area larger than the CED site itself and includes areas of varying degrees of risk to habitat and roadways. This risk depends on the proximity of the road to the watercourse in conjunction with hydrologic, hydraulic, geomorphic, and riparian character of the reach and CED site(s). Seven reports of reach analyses were reviewed, all with different degrees of risk assessment (Geoengineers, 2001; Geoengineers, 2003; Herrara Environmental Consultants, 2005; Herrara Environmental Consultants and Northwest Hydraulic Consultants, 2002; Lautz, K. et. al., 2004, Lautz, K. and J. Beall, 2005; Park, J. and R. Schanz, 2003). The Naches River reach assessment (Geoengineers, 2003) described risk criteria on pages 9-13. An extract of the graphic depicting risk areas for the Naches River is shown below. The CED site translates to the overlap of high environmental risk areas with moderate and high physical (road) risk areas or the overlap of high physical (road) risk areas with moderate and high environmental risk areas. The river

<table>
<tr><th>River Station (ft.)</th><th>Environmental Deficiency</th><th>Physical (Road) Risk</th></tr>
<tr><td>15,600</td><td rowspan="2">MINIMAL</td><td rowspan="3">MINIMAL</td></tr>
<tr><td></td></tr>
<tr><td>13,800</td><td rowspan="4">MODERATE</td></tr>
<tr><td>12,000</td><td rowspan="2">MODERATE</td></tr>
<tr><td></td></tr>
<tr><td>10,000</td><td rowspan="4">HIGH</td></tr>
<tr><td>7,800</td><td rowspan="2">HIGH</td></tr>
<tr><td></td></tr>
<tr><td>5,200</td><td rowspan="2">MODERATE</td></tr>
<tr><td>5,000</td><td rowspan="3">MINIMAL</td></tr>
<tr><td>4,700</td><td rowspan="2">HIGH</td></tr>
<tr><td></td></tr>
<tr><td>3,000</td><td></td><td></td></tr>
</table>

stations that define the linear boundaries of the CED site are 5,000 ft. and 10,000 ft., making the site 5,000 ft. long. For valid, easier comparisons of CED PIs across the state, a somewhat rigid definition of the CED site similar to this report is needed. The breadth (scope) of the CED correction is a different issue that can extend beyond the CED site (addressed by the value added adjustments discussed later in this report).

< Estimation of the width of the affected river area is also problematic. Most CED sites are more or less parallel to the road (i.e., the site is not a result of a river crossing). Therefore, the negative effects of the site are concentrated near the bank closer to the road. This characteristic can be accommodated by discounting width increments over 10 m by a square root factor. For example, a river with a width of 20 m would have an estimated affected area of $10 + \sqrt[2]{20-10}$, or 13 m. For smaller streams less than 10 m wide, the effects are probably full width and are not discounted. The 10-m threshold also accounts for those CED sites associated with river crossings, which tend to be associated with smaller watercourses and inappropriately sized or placed culverts. An example is Red Cabin Creek.

< Spawning area values are used for species complexes normally limited by spawning habitat (sockeye, chum, and pink salmon). They should be estimated at ordinary high water using the bank vegetation line or other evidence and should recognize only those areas within the CED site with suitable spawning gravel (APManual). Rearing areas should be estimated for the 60-day low flow as prescribed by the APManual for those species normally limited by rearing habitat (coho salmon, searun cutthroat, chinook salmon, steelhead, resident cutthroat/rainbow trout, and bull trout/Dolly Varden). Transport water is defined by stream gradient on page 37 of the APManual and should not be included as spawning or rearing area. It is important to note that all spawning area is considered rearing area, but not all rearing area is necessarily spawning area because of the gravel requirements for spawning. However, spawning area cannot exceed the total low flow site size.[2]

E = Effectiveness of the Prescribed Correction Modifier

< **E** is a modifier that accounts for the expected effectiveness of the CED correction in reducing future maintenance and repairs. This factor simultaneously addresses cost efficiency, safety, and fish protection because a reduced need for maintenance and repairs saves dollars and fish. It also inherently reflects a safer transportation corridor because the road is better protected and traffic diversions associated with road work are reduced. For a discussion of corrections whose

[2] Technical assistance for the determination of spawning and rearing area can be obtained through Don Haring, Division Manager for the Technical Applications Division (TAPPS) in the Habitat Program of WDFW (phone 360-902-2527).

breadth (scope) exceeds the CED site, refer to the value added section later in this report.

< A value of 1 means the expected frequency of maintenance and repairs is reduced to one or two in a 10-year period. Note that if the expected frequency is three or more after correction, then the site still qualifies as a CED, so the goal of eliminating the CED was not met. A value of 2 translates to no expected significant work activities at the site in the next 10 years. The assignment of the **E** value relies heavily on the engineering assessment of hydrologic expectations at the site in conjunction with specific physical conditions after correction. In the absence of such assessment, a default value of 1 should be used.

D = Species Condition Modifier

< **D** represents the status of species present at the CED site. It gives greater weight to less healthy species as listed in the three SaSI documents (1998 volume for bull trout and Dolly Varden, 2000 volume for coastal cutthroat, and the 2002 report for salmon and steelhead). In the absence of a SaSI assignment, stock condition should be estimated using the best available information from knowledgeable biologists.

3 = The condition of species is considered critical.

2 = The condition of species is considered depressed or a stock of concern.

1 = The species does not meet the conditions for 2 or 3.

C = Cost Modifier

< **C** represents the estimated cost of the project minus the cost savings for maintenance and repairs expected in the 10 years following correction (net cost). It gives greater weight to less costly projects and to those whose future cost savings are greater. This modifier depends on an engineering design for a selected correction option that allows a cost assignment accurate enough to fit the stratification below. It also depends on a record of previous maintenance and repairs. To some degree, the information needed for **F** and **E** above also provides input for the **C** value. For example, if a proposed correction reduces the frequency of expected repairs from 4 to 1 in the next 10 years and the historical repair costs were $1 million, then the expected savings would be $750,000. That coupled with, for example, a correction project cost of $5 million would translate

to a net cost of $4,250,000. It is suggested that future and past dollars not be adjusted because of the uncertainty of inflation and the relatively short time frame being considered (10 years forward or back). There is a logical question concerning expansion of a correction project's scope to address a whole reach or more than one reach to accommodate a watershed approach rather than confine the correction to the CED site alone. This would likely increase project cost, which could reduce the PI, so a mechanism is needed to reward the watershed approach. This is discussed in the value added section below.

3 = The net funds needed are # $1,000,000.

2 = The net funds needed are >$1,000,000 and #$5,000,000.

1 = The net funds needed are >$5,000,000.

In the absence of sufficient information, a default value of 2 should be used.

VALUE ADDED FACTORS

The $_{CED}$PI should be considered the scientifically based foundation for the prioritization process. Other (value added) factors can subsequently be applied to fit particular prioritization processes and needs. For CEDs on DOT-owned roadways, six factors appear most applicable: public safety, expected recurrence of maintenance and repairs, the breadth of the correction, listed species under the Endangered Species Act (ESA), the magnitude of matching funds, and the choice of correcting one versus few or many CED sites. The first two factors are actually addressed by the **E** and **C** values in the PI, which express the expected reduction in future maintenance frequency and cost and related reduction of safety concerns. Conversely, the other four factors need additional attention.

The breadth (scope) of correction (**B**) includes both the physical extent and salmonid habitat character involved in the correction work. This factor is very important because of its implication to watershed based biotic health. Correction efforts that include areas beyond the CED site itself obviously have a larger benefit. It should be noted that the extended work can include both in-stream and riparian improvements. The matrix below blends these two factors into a CED multiplier that ranges from 1.0 to 1.4. The physical extent factor is a linear increment measure and the habitat diversity addresses the transport, rearing, and spawning character of the extended work area. For example, with a CED site of 500m length and a correction that also includes a 1,500m (3X) increment of habitat improvement (2,000m total), the multiplier would be 1.1 if mostly transport habitat is addressed. Transport water is defined by stream gradient for each fish species on page 37 of the APManual. If at least 50% of the extended length includes rearing area for one or more species, the multipliers are increased. If, in addition to the rearing area, at least 10% of the incremental length includes spawning area, multipliers are increased further. It is important to reiterate that all spawning area is considered rearing area, but not all rearing area is necessarily spawning area because of the gravel requirements. In this example, the multiplier would increase from 1.1 to 1.2 if the rearing threshold is met and to 1.3 if the spawning threshold is also met.

B Values based on 2 Variables	Habitat Increment Length >0.2X & up to 2X of CED Length	Habitat Increment Length >2X & up to 4X of CED Length	Habitat Increment Length > 4X of CED Length
Habitat Increment Involves Mostly Transport Water	1.0	1.1	1.2
Habitat Increment Comprised of at Least 50% Rearing Area	1.1	1.2	1.3
Habitat Increment Comprised of at Least 50% Rearing Area and at Least 10% Spawning Area	1.2	1.3	1.4

If the status of one or more species affected by a CED site is listed (**L**) by the Endangered Species Act as “candidate,” “threatened.” or “endangered,” then additional multipliers are applied. This information can be found on the National Oceanic and Atmospheric Administration website (http://www.noaa.gov/1salmon/salmesa/pubs/1pgr.pdf). This should not be interpreted as giving too much weight to depressed fish when the base PI also applies additional emphasis to depressed and critical stocks as defined in the SaSI reports. The major reason is that resolution of SaSI is at the stock level for a species while the resolution of ESA is at a broader species level. Using both of these stock status tools ensures additional consideration for unhealthy fish.

< If one species in a CED site is listed under ESA, the **L** multiplier is 1.1. If two or more species are listed, the **L** multiplier is 1.2.

Matching funds (**M**) outside the normal funding base for DOT projects express interest of other parties and warrant additional weight to the CED correction project. Such funds can come from various federal, state, and local jurisdictions and authorities. The weighting factor is expressed as the following formula, with a maximum value of 1.2.

< **M**= 1 + (% Match/100)

The % match is calculated as a proportion of total project cost, not the proportion of the normal DOT funding base. For example, if a $4.0 million project is funded by $3.2 million gas tax dollars and $0.8 million federal funds, then the weighting factor would be 1 + (20%/100), or 1.2. If the proportion of federal funds exceeded 20%, the factor would remain at 1.2. The reason for this limit is to avoid masking the other important weighting factors.

The maximum effect of the three aforementioned value added weighting factors would be a two-fold increase in the base PI for a CED site. That is, (1.4)(1.2)(1.2) = 2.0. This is reasonable because larger multipliers would mask the importance of the base PI.

One of the most challenging questions for project managers is whether to concentrate on correcting one or a very few high priority CEDs versus correcting more less-expensive problems, albeit some have lower PIs. There are advantages to concentrating effort within one watershed, therefore maximizing the chance of making that watershed healthy. This approach would certainly include some lower priority projects and also has the disadvantage of ignoring other watersheds. This contributes to a decline in overall watershed health on a broad scale. The other approach selects only the highest priority projects, which tends to spread project activity among watersheds. This contributes to broad scale watershed improvement, but does not normally maximize an individual watershed’s health. The optimum project selection probably blends the two approaches, which requires some quantifiable, blended prioritization. The following formula combines the individual PIs being considered into an aggregate PI that can be compared to individual PIs and used to compare different aggregations:

$$\sum PI_{eachproject} \Big/ \sqrt[4]{\sum PI_{eachproject} / PI_{highest}} = \mathrm{PI}_{aggregate}$$

It is intuitive that any project combination being considered for replacing a single project of largest PI will have a greater chance of having a larger aggregated PI when more sites are aggregated. In addition, if one or more of the sites in the aggregate has a PI that approaches the largest PI, the aggregate's chance of having a favorable priority is increased. Consider the example of four CED correction projects whose PIs are 100 (site1), 60 (site2), 60 (site3), and 10 (site4), where options of correcting one, two, three, or four sites are contemplated. The results of the PI assessment using the aggregate formula are summarized in the following table.

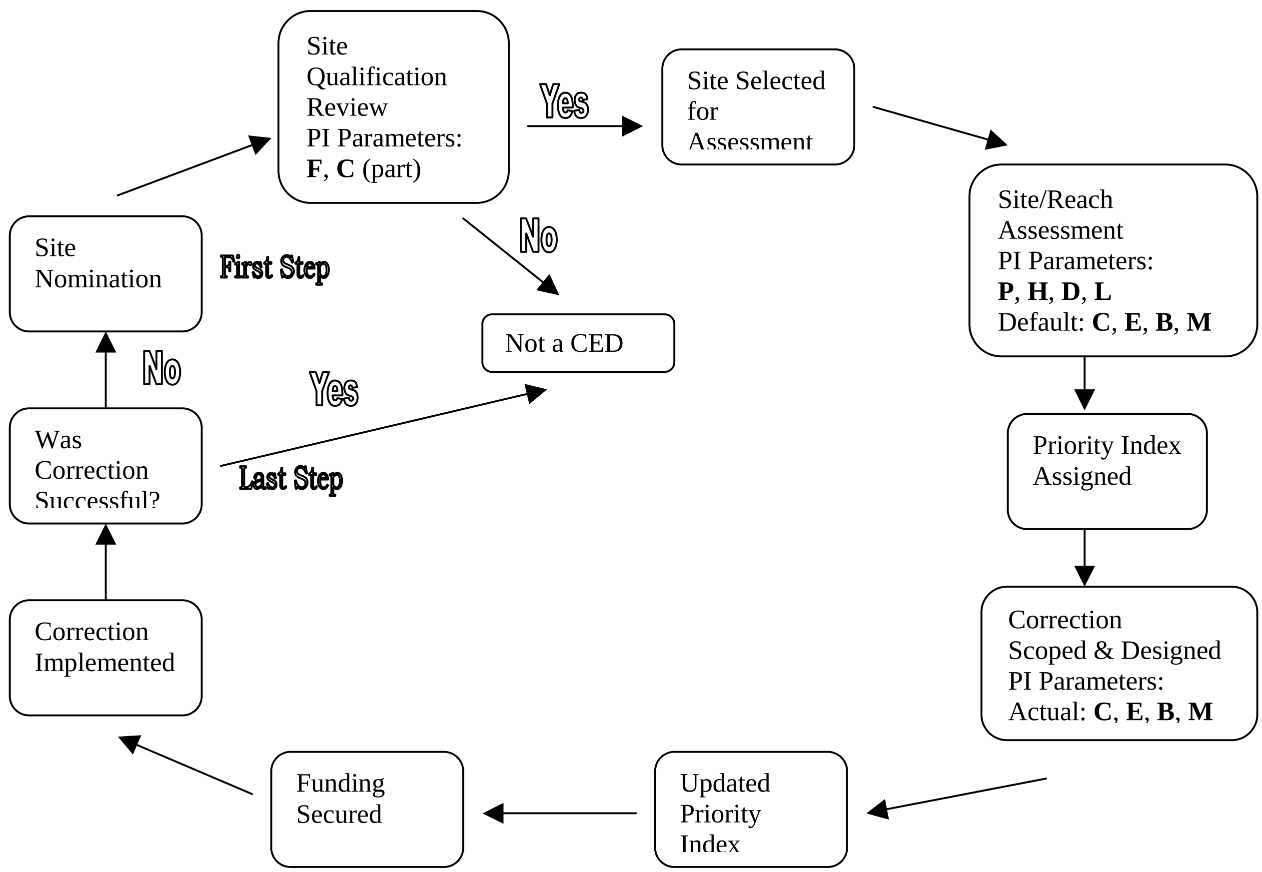
Sites Considered	Single Site PI	Two-Site Aggregate PI	Three-Site Aggregate PI	Four-Site Aggregate PI
1,2,3,4				187
1,2,3			181	
1,2,4			149	
1,3,4			149	
1,2		142		
1,3		142		
1,4		107		
2,3,4			107	
2,3		101		
1	100			
2,4		67		
3,4		67		
2	60			
3	60			
4	10			

Any combination that includes Site 1 obviously has an aggregate PI that exceeds any individual PI. However, if combinations are considered that exclude Site 1, only two situations demonstrate clear merit. These include a Sites 2 and 3 combination (aggregate PI of 101) and a Sites 2,3,and 4 combination aggregate PI of 107). However, if either Site 2 or 3 had a PI of 55 rather than 60, the two-site combination would not be favorable (aggregate PI of 98 compared to 100 for Site 1). The three-site combination would still have a larger aggregated PI (104) than site 1 alone.

Aggregated PIs should be calculated before value added multipliers (**B**, **L**, and **M**) are applied because the calculation of an aggregated PI is complicated if two or more CED sites are connected by the expanded work area to accommodate a watershed approach. In such cases the position and length of the expanded area (upstream or downstream of CEDs) and the transport, rearing, and spawning characteristics of the expanded area confound the apportionment of the incremental habitat length. Applying a single **B** multiplier is much easier and avoids many assumptions of apportionment.

PROCESS FOR PRIORITIZING CEDS

The process for prioritizing CEDs is collaborative and includes technical, construction/maintenance, and policy components. It is an integral part of a cycle that includes CED site identification, prioritization, scoping, design, funding, permitting, construction, and evaluation. Data for the priority index are supplied in several steps of the cycle, which is summarized in the following diagram. The first step is the nomination of a potential site, typically by WDFW field biologists or DOT maintenance and engineering staff. This does not preclude nomination by other interested parties such as treaty tribes, regional fisheries enhancement groups, conservation groups, and others associated with watershed and fish recovery initiatives.



Once a site is nominated, it is reviewed by the CED work group. It is during this step that information for frequency of repair (**F**) and the negative component of cost (**C**) are obtained for the PI model. If it meets the qualifications for a CED, then recommendation for a site/reach assessment is forwarded to the CED committee. With committee approval, DOT schedules or contracts for the assessment, which is a process that includes involvement of a WDFW field biologist to ensure fish production data are secured. The necessary components of the assessment are compiled by the biologist into a PI that includes production potential (**P**), affected habitat (**H**), and SaSI (**D**) and ESA (**L**) status. Default values for net cost (**C**), effectiveness of repair (**E**), breadth of correction (**B**), and matching funds (**M**) are used in the PI, which is then forwarded to the CED work group. The PIs for all the CED sites are assembled by the work group for review by the committee, which in turn initiates the process for scoping and design of selected projects. The involvement of the field biologist in the scoping and design step is advantageous to ensure timely permitting before the project begins. The design option selected is reviewed by the work group, which also checks and refines the PI based on the breadth of the correction (**B**) or other factors discovered in the scoping process. This includes any adjustments to **C, E,** and **M**. The cost of the selected design option as well as any DOT benefit assessments are used in the normal DOT funding process to secure dollars for the project (see the success measures section of this report). Once the project is permitted and built, the engineer and biologist review the project for the effectiveness of the correction. With a suitable report and concurrence of the work group, the project is removed from the CED list; otherwise it remains as an uncorrected CED.

SUMMARY OF TEST PRIORITIZATION

The prioritization methodology was tested on 12 individual sites and five site combinations on the North Fork Nooksack River, Snoqualmie River, Sauk River, Hoh River, White River, Naches River, and Red Cabin Creek (Skagit River). The information used was extracted from the reach analyses for these systems as well as SaSI and NOAA documents for fish stock status. In most situations, measurements were coarse because large scale drawings, maps, or photographs were used and CED site delimitations and qualifications were taken at face value from the reports. Rearing area was assumed to be 90% of total affected area and spawning area assumed to be 40%. Had the reach analyses been refined with this prioritization methodology in mind and with biological and engineering disciplines both involved, the information would have been more precise. For most sites and site combinations, default values for frequency of repair (**F**), effectiveness of the retrofit (**E**), net cost (**C**), breadth of repair (**B**), and matching funds (**M**) were used. Exceptions are noted in the summary table below. Notwithstanding those limitations, the test was robust and appropriate for demonstration.

Sites Considered	Default Parameters	Single Site PI	Two-Site Aggregate PI	Three-Site Aggregate PI
NF Nooksack MP30 (Warnick Bridge) NF Nooksack MP30.5 (above Warnick Bridge) NF Nooksack MP45 (non-anadromous zone)	F,E,C,B,M			100.50
NF Nooksack MP30 (Warnick Bridge) NF Nooksack MP30.5 (above Warnick Bridge)	F,E,C,B,M		97.76	
NF Nooksack MP30 (Warnick Bridge)	F,E,C,B,M	66.55		
Snoqualmie/Falls City Site 4 Snoqualmie/Falls City Sites 1,2,,& 3	F,E,C,M B=1.2		64.10	
NF Nooksack MP30.5 (above Warnick Bridge)	F,E,C,B,M	44.58		
Sauk River/SR530 MP59.3	F,E,C,B,M	44.18		
Hoh/SR101 RM 12.5 Hoh/SR101 RM 13.5	F,E,C B=1, M=1.2		39.38	
Naches Station 5000-8000	F,E,C,M B=1.3	34.47		
Snoqualmie/Falls City Site 4	F,E,C,B,M	32.32		
Snoqualmie/Falls City Sites 1,2,,& 3	F,E,C,B,M	30.82		
Hoh/SR101 RM 12.5	F,E,C B=1.2, M=1.2	30.51		
White River/SR410 RM58.7 White River/SR410 RM59.2	F,E,C,B,M		19.52	
Red Cabin Cr/SR20	E,C,B,M F=1	18.04		
Hoh/SR101 RM 13.5	F,E,C,B,M	16.79		
White River/SR410 RM58.7	F,E,C,B,M	11.97		
White River/SR410 RM59.2	F,E,C,B,M	11.01		
NF Nooksack MP45 (non-anadromous zone)	F,E,C,B,M	3.47		

The single site PIs ranged from a high of 66.55 for the Warnick Bridge site on the North Fork Nooksack to a low of 3.47 for the site in the non-anadromous zone of the same river and yield an appropriate spread for selecting projects for retrofit. With value added parameters excluded, the range was 55.46 to 3.47, which is similar to that experienced in the fish passage prioritization. The number of adult equivalent salmonids affected on an annual basis averaged 3,395 and ranged from 24,915 to 72. It should be noted that the site measurements for the North Fork Nooksack are the most questionable. The large PI for the Warnick Bridge site could easily be significantly smaller if the site length is less than the notation in the report. The importance of value added parameters for individual sites is demonstrated by the Hoh River site at RM 12.5. The **B** value of 1.2 and the **M** value of 1.2 raised the PI by a factor of 1.44 to 30.51. Even more significant is the effect of a 1.3 **B** value for the Naches River site, which elevated its ranking above the two sites on the Snoqualmie River and the site at RM 12.5 on the Hoh. The value of **B** in this case was calculated based on an assumption of instream and riparian enhancements in the whole reach in the Naches River report.

The aggregate PIs calculated for the site combinations affirmed that any combination that included a site with a large individual PI also retained its high ranking. This was shown for the two- and three-site combinations for the North Fork Nooksack that included the Warnick Bridge site. Note that the inclusion of the site in the non-anadromous zone (aggregate PI of 100.50) added little to the aggregate PI for the two site combination (97.76). Unless the cost of adding this site to a retrofit schedule is small, it would be difficult to justify its substitution for another site with much larger PI on another river system. Of interest is the elevation of site combinations in the Snoqualmie, Hoh, and White rivers above several individual sites. Such substitution in a retrofit schedule may be appropriate if the costs of the combinations are similar or less than for a single site with a large PI, particularly if one objective is to complete all sites within a river system. The importance of the value added factors for site combinations is shown for the Hoh River, where the **M** value of 1.2 elevated the ranking for this combination above the individual site on the Naches river.

This test demonstrates the need for standardization of CED site boundaries and the inclusion of biological and engineering expertise in the prioritization process. Scale drawings of the sites would facilitate calculations. Inclusion of spawning and rearing areas in the drawings would be helpful but not essential if the biologist can apply an accurate apportionment to the site as a whole. It is also important to refine the PI based on the scoping process with any subsequent adjustments to the default values for **B**, **C**, **E**, and **M**.

SUCCESS MEASURES

The PI blends the biological, physical, and fiscal characteristics of a CED site into a scientifically based index that not only prescribes a logical priority order of correction but also provides key measures for expected success. When the PI numbers for the 12 test sites are used as an example, it is very easy to rationalize correction of sites with a PI greater than 25 (such as the two lower sites on the North Fork Nooksack River, the Sauk River site, the Naches River site, the two sites on the Snoqualmie River, and the lower site on the Hoh River) before correcting sites on the lower end of the scale (such as the two sites on the White River and the uppermost site on the North Fork Nooksack River. This does not infer that sites with lower PIs will not be corrected, but rather that the overall benefit of the correction program will be maximized by correcting sites in priority order. A convenient way to view this is to understand the number of adult equivalent fish that will be potentially produced in any given time span with earlier correction of CEDs with higher PIs.[3] For a very simple example, assume four CED sites are corrected the second year of each of the next two bienniums and that the sites being considered are the two lower sites on the Nooksack River (PIs of 66.55 and 44.58), the site on the Sauk River (PI of 44.18), the Naches River site (PI of 34.47), the upper Hoh River site (PI of 16.79), the two sites on the White River (PIs of 11.97 and 11.01) and the uppermost site of the Nooksack River (PI of 3.47). If the PIs are used to order correction, then three years of benefits (assuming no benefits for the first year of the first biennium) of the first four sites equal 3(24,915+5,018+5,066+1,204), or 108,609 adult equivalent fish. One year of benefits (assuming no benefits for the first three years of the two bienniums) for the last four sites equal 1(414+144+103+72), or 733. The total four-year fish benefit in this PI-prescribed correction schedule totals 109,342 fish. This stream of benefits would obviously extend indefinitely into the future assuming the CED corrections do not fail soon after four years. Conversely, if the order of correction were reversed, three years of benefits of the last four sites would equal 3(414+144+103+72), or 2,199, and one year of benefits of the first four sites would equal 1(24,915+5,018+5,066+1,204), or 36,203, with total four-year benefits of 38,402 fish. Using the PI to prescribe order of correction obviously maximizes fish production benefits (109,342 fish versus 38,402 fish in a four-year time span). It is also important to note that significant proportions of these fish are depressed and/or listed under ESA, which further elevates their importance. From a broader perspective, fish benefits also represent only a snapshot of the whole ecosystem that includes the complex of fauna, flora, total landscape (including the watercourse itself, riparian areas, wetlands, contiguous non riparian areas, aquifers, and estuarine areas) and all the

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[3] The adult equivalent salmonids affected on an annual basis by a CED are the product of **F**, **P**, and **H** and are shown in the corrected FPH column of the appendix spreadsheets.

processes affecting these. Valuation of the ecosystem benefits of correcting CEDs for this complex is clearly daunting, but the benefits are at least minimally reflected by fish benefits.

Although the PI methodology is driven by fish benefits, there are other considerations in the model that are related to safety and cost efficiency. These include the safety concerns that are minimized with corrections that eliminate or minimize future repair and maintenance work. These are part of the net cost calculation in the PI. In addition, there are infrastructure benefits because even if future savings from lower frequency of repair are accounted for, there is still an additional intrinsic value to the infrastructure improvement. In most cases, the timely retrofit of a CED site also will circumvent future catastrophic road damage, the repair of which would normally exceed the correction of the CED. These considerations coupled with fish benefits should easily substantiate the overall cost efficiency of the CED correction program. An acceptance of overall program cost efficiency would then reduce the arguments to the rate of CED correction using the prioritization scheme described in this report.

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APPENDIX A (North Fork Nooksack River/SR 542 PIs)

APPENDIX B (Red Cabin Creek {Skagit}/SR 20 PI)

APPENDIX C (Sauk River/SR 530 PI)

APPENDIX D (Snoqualmie River/SR 202 PIs)

APPENDIX E (Hoh River/SR 101 PIs)

APPENDIX F (White River/SR 410 PIs)

APPENDIX G (Naches River/SR 12 PI)